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Monitoring Completed Navigation Projects, Lessons Learned IV

by Robert R. Bottin, Jr.

PURPOSE: The Coastal Engineering Technical Note (CETN) herein provides a summary of lessons learned and significant results for projects monitored under the Monitoring Completed Navigation Projects (MCNP) Program.

GENERAL: This CETN is the fourth of a series summarizing lessons learned and project results from the MCNP Program, formerly the Monitoring Completed Coastal Projects (MCCP) Program. Lessons learned from previously monitored projects may be obtained from USACE (1992); USACE (1993); and Bottin (1997). This CETN covers four comprehensively monitored projects for which reports have been prepared: St. Joseph, MI (Parson and Smith 1995; Parson, Morang, and Nairn 1996; Nairn et al. 1997); Agat Harbor, Guam (McGehee and Boc 1997); Colorado River, TX (King and Prickett 1998); and Redondo Beach, CA (Rhee and Corson 1998; Sabol 1996). The CETN also includes four projects monitored under the Periodic Inspections work unit of the MCNP program: Humboldt Bay jetties, CA (Bottin and Appleton 1997); Ofu Harbor breakwater, American Samoa (Bottin and Boc 1997); Manasquan Inlet jetties, NJ (Bottin and Rothert 1999); and Burns Harbor breakwater, IN (Bottin and Tibbetts 2000).

The elements of the comprehensively monitored projects included the measurement of waves, wave-induced currents, water levels, tidal elevations, tidal currents, bathymetry, beach profiles, and sediment sampling as well as site inspections and photographs. Elements of the projects monitored under the Periodic Inspections work unit involved predominantly photogrammetric surveys and analyses of structures, with limited ground truthing surveys, and broken armor unit surveys.

COMPREHENSIVELY MONITORED PROJECTS

St. Joseph, MI

St. Joseph, located on the southeastern shore of Lake Michigan, was monitored during the period July 1991 – June 1994. Jetties, constructed at the mouth of the St. Joseph River in 1903 to stabilize the entrance, have proven to be responsible for downdrift shoreline erosion. Monitoring was performed to study native beach sediment characteristics and geology at the site and to evaluate the behavior of coarse-grained nourishment material in the project area. Lessons learned and significant results include:

- a. The shoreline in the vicinity of St. Joseph exhibits highly irregular sedimentation zonations and wide ranges of sediment size gradation as opposed to classic sandy beach characteristics found on barrier island ocean coasts.

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- b. The validity of sampling techniques and methodologies used for sandy shorelines is questionable when used in areas similar to St. Joseph where highly irregular zonations and wide sediment gradations exist. To provide a realistic representation of native beach characteristics, sampling techniques should be based on unique sediment characteristics and natural variations in geology.
- c. A cohesive sediment substratum at St. Joseph plays a dominant role in the change of the shoreline. Where the cohesive glacial till is exposed, downcutting is likely to occur during most wave conditions. Unlike unconsolidated sand and gravel, which may come and go under different energy regimes, fine-grained cohesive material, once eroded, cannot reconstitute itself and is removed from the beach system. The profile erosion that occurs during this process is permanent.
- d. Historical trends indicate the beach nourishment program has been successful in mitigating lake bed lowering rates south of the jetties between the period 1965 – 1991 (with a tenfold decrease in lake bed lowering rates in some areas). Between 1991 – 1995, however, acceleration of lake bed erosion occurred (30 to 50 percent higher than earlier periods). During this period, annual nourishment volume decreased by 50 percent, which may partly explain the accelerated erosion rates.
- e. Study results indicate that the fillet beach immediately south of the jetties would probably remain stable without beach nourishment. The area south of the fillet beach is definitely benefiting from the nourishment program with a stable shoreline being maintained. The coarse grain sediment component of the fill protects the till under the upper beach from downcutting during storms. South of this sector, however, the beach nourishment program is not providing much benefit to the stability of a revetment or to the lake bed offshore of the revetment. In addition, about 50 percent of the beach fill is being deposited permanently on the lake bed in this sector due to a depression. The extreme southerly sector of the project is experiencing a deficit of material compared to historic supply rates. Accelerated offshore lake bed lowering as well as shoreline recession are occurring.
- f. Based on the monitoring results, the study recommends the entire allotment of beach nourishment be placed on the extreme southerly sector of the project. Additional shoreline structures to the south of the area (to counteract erosion) may then be avoided. The shoreline between this sector and the jetties could be stabilized with other site-specific measures (i.e., rock headlands or breakwaters).

Agat Harbor, Guam

Agat Harbor, located on the western side of the island of Guam, was monitored during the period February 1991-April 1994. Monitoring was performed to determine wave transformation across coral reefs, wave and surge levels behind coral reefs, wave transformation down steep-sided channels, wave-induced circulation on a flat reef, response of the project and adjacent shorelines, and to validate the Harbor Shallow Water (HARBS) model. Little engineering data exists relative to design guidance for wave characteristics and surge levels on coral reefs. Lessons learned and results include:

- a. Most hydrodynamic data obtained during the monitoring effort represented mild conditions. Therefore, some of the quantitative objectives of the study were not met because of the lack of data during the rare high-energy events.
- b. Wind waves dissipate most of their energy in breaking at the reef face. Wave energy propagates across reef flats as bores, moving water shoreward, that returns seaward through breaks in the reef face. Agat Harbor and its entrance channel provided such a pathway.
- c. Wave heights on the reef flat do not increase appreciably as wave height offshore increases, but the amplitude of seiche of the entire reef is affected by incident energy. Wave groups (surf beats) with periods near the principal seiche modes of a reef flat may induce harmonic coupling.
- d. The combination of seiche, return flow from wave setup, and mass transport of bore-like waves can result in large currents running parallel to shore. For structures located on the reef flat, forces due to the resulting currents may be of larger magnitude than forces due to the wind waves themselves.
- e. There is no indication that wind waves on a flat reef will exceed the depth-limited breaking criteria used for sloping beaches. The highest wave height to water depth ratio obtained was 0.72, slightly lower than the 0.78 criteria used for sloping beaches.
- f. Insufficient wave data were obtained from the sensors inside the harbor to validate the HARBS model. Peak period on the reef flat bears little resemblance to the incident wave period. Long period waves dominated the signal. The model was conducted for wind waves in the 8 to 20 sec range, however, wave periods measured in the harbor were much longer (100 to 200 sec).
- g. Insufficient wave data were obtained to determine wave transformation down steep-sided channels. During simultaneous operation of both sensors in the channel (for correlation), wave conditions were always low.
- h. The detached breakwater design promotes flushing of the harbor, but can result in a significant influx of sediment during high-current events.

Colorado River, TX

Colorado River, located on the Texas coastline near the town of Matagorda, was monitored during the period May 1990 – September 1992. Monitoring was performed to evaluate the design and efficiency of a weir jetty system and adjacent impoundment basin at the mouth of the river. Lessons learned as well as significant results include:

- a. The weir-jetty system at the mouth of the Colorado River has had minimal impacts on adjacent beaches.

- b. The weir is in the proper cross-shore location, is at the correct elevation, and is the proper length.
- c. The longshore transport rate was substantially underestimated during the design of the weir-jetty system. The impoundment basin was designed for a littoral drift transport rate of 230,000 cu m (300,800 cu yd), however, data indicate a net transport rate (in the direction of the weir) on the order of 510,000 cu m (667,000 cu yd). This resulted in the impoundment basin and entrance channel shoaling substantially more rapidly than expected following construction. The creation of a safe, navigable inlet was the primary purpose of the construction, and the shoaling of the inlet mouth adversely impacts navigation.
- d. Good, reliable estimates of the longshore transport rate are needed prior to jetty and impoundment basin design. It is recommended that computations of these rates be based on at least two years of onsite wave data. Failure to do this may lead to uncertainties in anticipated dredging costs.
- e. Consideration should be given to enlarging the impoundment basin at Colorado River. Unfortunately, available area between the jetties is limited. Future project designs should have flexibility to allow for modifications of the size and shape of the impoundment basin based on operational experience.
- f. Data obtained indicated that as the impoundment basin filled, it became less efficient at retaining sediments. This may occur because the bottom is subjected to increased wave and current forces as it fills.
- g. Most weir-jetty systems are located at inlets that typically have minimal amounts of inland-derived sediments. Data obtained at the mouth of the Colorado River suggests significant volumes of riverine materials depositing in the entrance channel and impoundment basin. Future designs at river mouths that carry large sediment loads should consider situating the impoundment basin so that minimal trapping of river-borne sediments occur (i.e., through the use of training dykes or by physically separating the basin from the river mouth).

Redondo Beach, CA

Redondo Beach, located on the southern California coast, was monitored during the period October 1992 – June 1994. Monitoring was performed to compare observed offshore wave transformation (as measured in the prototype) with theoretical wave propagation models for this area of steep, complex bathymetry. Field data measurements were compared with results from the Regional Coastal Processes Transformation Model (RCPWAVE) and from a spectral refraction model (STWAVE), which treats the propagation of spectral waves rather than monochromatic waves as in RCPWAVE. Conclusions from the study include:

- a. Modeling wave transformation over a variable sea bottom remains a difficult task in most cases. Analytical solutions limit themselves only to simple geometry, and numerical

treatments base their predictions on the fundamental assumption of "slowly varying" sea depth. The difficulty in modeling the Redondo Beach site is heightened by the presence of a deep submarine canyon offshore which affects waves from the predominant direction of attack.

- b. Computations from both RCPWAVE and STWAVE are in poor agreement (low correlation coefficients) with field measurements when swell heights are greater than 1.5 m (5 ft).
- c. In general, RCPWAVE tends to overestimate wave heights. Depending on the location, computed wave height ranged from 19 to 62 percent greater than those observed.
- d. STWAVE wave heights appear to be more accurate than RCPWAVE, but in general, they were underestimated. Computed wave height ranged from 12 to 13 percent less than those observed.
- e. Both field measurements and model computations indicate no significant tidal influence on wave transformation.

PERIODIC INSPECTION PROJECTS

Selected coastal structures are periodically monitored to gain an understanding of their long-term structural responses to their environments. In general, relatively low-cost sensing tools and techniques, with limited ground truthing surveys, are the primary inspection methods used in the monitoring efforts. Photogrammetric analysis has proven to be an excellent tool in obtaining precise positions of above-water armor units on the structures monitored. Since the last MCNP lessons learned CETN was published, base conditions have been established for Humboldt Bay jetties, CA, and Ofu Harbor breakwater, American Samoa. Future periodic monitoring will be compared to base conditions for both projects to determine the long-term responses of their armor units. Manasquan Inlet jetties, NJ, and Burns Harbor north breakwater, IN, have been revisited through the periodic inspection work unit with monitoring data collected over a period of time. Lessons learned and significant results for the latter two projects include:

Manasquan Inlet jetties, NJ

Monitoring data for the period 1994-1998 were analyzed for the Manasquan Inlet dolos-armored jetties. Work entailed re-establishing targets and conducting limited ground-based surveys, aerial photography, photogrammetric analysis, and a broken armor unit survey for comparison with data obtained in 1994. Results of the monitoring effort indicated that dolosse movement was less dynamic during the period 1994-1998 as opposed to previous survey periods. Maximum horizontal movement detected was 0.7 m (2.3 ft), and maximum vertical displacement was 0.3 m (1.2 ft). In general, however, most movements in both the horizontal and vertical directions were less than 0.06 m (0.2 ft). Horizontal movement for the majority of the dolosse was relatively uniform (the entire unit moved in the same direction as opposed to rotating). Of the units that rotated, however, the majority on the north jetty rotated in a clockwise direction, while those on the south jetty, rotated in a counterclockwise direction. Vertical motions revealed that some units moved upward slightly and some subsided slightly. Average vertical movements

were on the order of about 0.06 m (0.2 ft). Even though major storms occurred during the period, the 14,515-kg (16-ton) dolosse appeared to have settled into the structure becoming relatively stable.

During October 1997, void areas in both jetties (identified in previous surveys) were rehabilitated with 17,235-kg (19-ton) CORE-LOC armor units. Twenty-nine CORE-LOCs were placed on the north jetty and 16 on the south jetty interlocking with the existing dolosse. Some dolosse were repositioned to improve interlocking and provide space for the new CORE-LOCs into the overall protection scheme. Several broken dolosse also were removed from the structures. The new CORE-LOC armor units were targeted and base data relative to their positions were established.

Eight broken dolosse armor units, four on each structure, were documented during the 1998 survey. Two were newly broken since the 1994 survey. A total of 17 broken units were observed in 1994, but many were removed during the 1997 CORE-LOC rehabilitation. The jetties appear to be in excellent condition.

Burns Harbor north breakwater, IN

Monitoring data for the period 1994-1999 were analyzed for the Burns Harbor north breakwater. This is a rubble-mound structure armored with 9,100 to 13,600 kg (10 to 15 ton) rectangular cut Indiana Bedford limestone blocks. Work involved re-establishing targets and photo control points and conducting limited ground-based surveys, aerial photography, photogrammetric analysis, and a broken armor stone survey for comparison with data obtained in 1994. Results of the monitoring effort indicated continued loss of structure elevation. Approximately 46 percent of the total length of the breakwater was below the design crest el of +4.3 m (+14 ft) versus 24 percent in 1994. Also, about 11 percent of the structure was below an el of +3.7 m (+12 ft) in 1999 versus 4.6 percent in 1994. Both surveys indicated crest width along the breakwater narrower than design and slopes on the harbor side of the structure steeper than design.

A total of 225 broken armor units were documented during the 1999 survey versus 165 during the previous one. Data indicated the majority of additional stone breakage occurred on the harbor side of the structure, as opposed to the lake side. As in the previous survey, higher concentrations of broken stone were noted on the eastern one-third of the breakwater during the current monitoring effort.

To reduce wave heights at the breakwater and minimize further damage, a submerged reef breakwater was constructed lakeward of the original structure during the construction seasons between June 1995 and August 1998. The photogrammetry conducted in 1999 not only quantified changes since 1994, but established new base conditions for the structure upon which the performance of the reef breakwater can be evaluated in future years.

ADDITIONAL INFORMATION: For additional information contact Mr. Robert R. Bottin, Jr., MCNP program manager, Harbors and Entrances Branch, Coastal and Hydraulics Laboratory, U.S. Army Engineer Research and Development Center, at 601-634-3827 or e-mail r.bottin@cerc.wes.army.mil.

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